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Geology.

Ballycastle
coalfield
Wall



Fig. 1.

CLIFF SECTION AT GOBB COLLIERY.

(See page 265.)

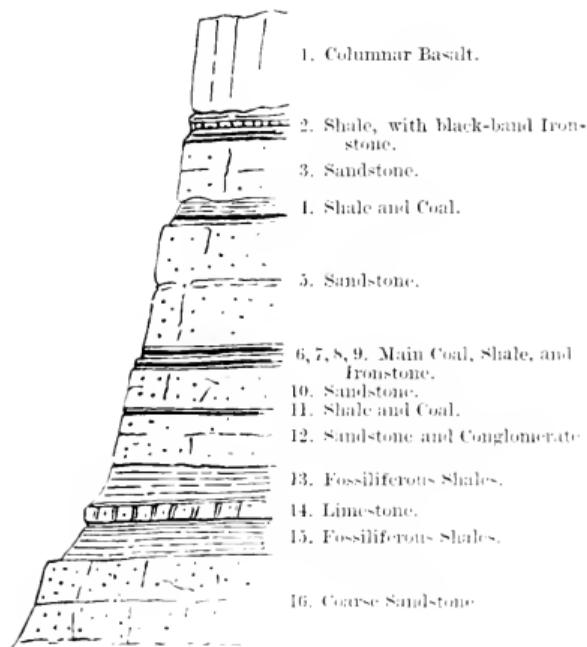
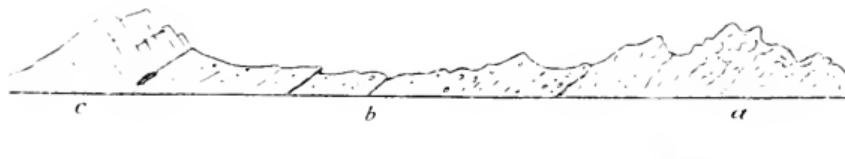


Fig. 2.

COAST SECTION AT MURLOCH BAY, SHOWING THE BASEMENT BEDS OF THE CARBONIFEROUS SERIES.



- c* Bedded columnar Basalt.
- b* Yellow and White Sandstone and Quartzose Conglomerate at the base of the Carboniferous Series; resting on Foliated dark Mica Schist.
- a* Foliated dark Mica Schist, with numerous Veins of white Quartz.

J. F. Campbell Esq. F.G.S.

From the Author

ON THE

GEOLOGICAL AGE OF THE BALLYCASTLE COAL FIELD,

AND ITS RELATIONS TO THE CARBONIFEROUS ROCKS OF THE
WEST OF SCOTLAND.

BY EDWARD HULL, M.A., F.R.S., F.G.S.,

DIRECTOR OF THE GEOLOGICAL SURVEY OF IRELAND;

WITH PALEONTOLOGICAL NOTES,

BY W. H. BAILY, F.G.S., AND L.S.

Read before the Royal Geological Society of Ireland, on January 11, 1871.

HAVING recently had occasion to visit the coal-field of Ballycastle for the purpose of inquiring into its mineral resources on behalf of the Royal Coal Commission, I was struck by several features of resemblance which the rocks present to those of the Carboniferous district of the West of Scotland; and I have thought that a comparison of the geological relations of the two districts on opposite sides of the Irish Sea, may not prove uninteresting to the Society.

I wish in the first place, however, to state that I have no intention to present a general description of the Ballycastle coal-field to the Society on this occasion, or to refer to the subject further than may be necessary for the purposes of the comparison aforesaid. In course of time a complete examination of that interesting district will be undertaken by the Government Geological Surveyors, and after the able report made in 1829 by Sir Richard Griffith to the Royal Dublin Society,* any attempt at a general description of the structure and resources of this little coal-field would be, meanwhile, simply superfluous.

Though my visit to Ballycastle in the spring of this year extended only over a few days, yet, what I saw sufficed to convince me, that the Carboniferous rocks of that district are referrible to the type of those of the West of Scotland rather than to those of Tyrone, Leitrim, Kilkenny, and the South of Ireland, as well as of England and Wales.

Now, in order properly to explain my meaning, it may be useful to point out the true geological horizon of the coal-fields I have referred

* "Geological and Mining Survey of the Coal Districts of Tyrone and Antrim," by Richard Griffith. Dublin, 1829.

to, and I shall commence by referring briefly to those of England and Wales.

Geological Horizon of the English and Welsh Coal-fields.

The general succession of these beds is as follows :—

Stage E. Upper, middle, and lower coal-measures.

 " D. Millstone grit.

 " C. Yoredale rocks.

 " B. Carboniferous limestone.

 " A. Lower limestone shale (forming the base of the Carboniferous rocks).

The above is the typical succession of the different stages throughout the whole of the coal-fields except those of the extreme north of England, where certain changes occur to which I shall presently allude. But throughout the English coal-fields, it is only in stage E that beds of workable coal occur, and to these the term "coal-measures," is strictly confined.

South of Ireland.—The coal-fields of Kilkenny, King's County, Kerry, and Clare, have like those of England, a basis of Carboniferous limestone ; and still retaining, by way of comparison, the stages as developed in England, are capable of being arranged as follows :—

Stage E. (Not represented).

 " D. (Doubtfully represented).

 " C. So-called "coal-measures" of this district.

 " B. Carboniferous limestone.

 " A. Carboniferous slate, or lower limestone shale, &c.

Upon comparing these stages with those of England, it will be observed that "the coal-measures" of this part of Ireland occupy an horizon altogether different from, and considerably lower down than, the true coal-measures of England.

In the north of Ireland, however, the series approximates to that of England, as will be seen by the following comparison of the strata of the Tyrone and Connaught coal-fields.*

Connaught and Dungannon Coal-fields :—

Stage E. Coal-measures (with coal, &c.).

 " D. Millstone grit, } well developed in County Leitrim,

 " C. Yoredale rocks, } not so well in Tyrone.

 " B. Carboniferous limestone.

 " A. Lower limestone shale, yellow sandstone, and conglomerate.

* See Griffith's "Report on the Connaught Coal-field," 1818, pp. 20-23 ; and the late Mr. G. V. Du Noyé's Description of this Coal District, in the "Geologist," 1854.

Changes in the Carboniferous Rocks of England towards the North.

Returning now for a little to England in order to examine the changes which the Lower Carboniferous rocks undergo in their extension northwards, it is well known as the result of the labours of Sedgwick, Phillips, and other geologists, that the Carboniferous limestone gradually deteriorates (as such) as it extends towards the Scottish Borders. In this direction, beds of shale and sandstone with coal make their appearance, dividing the solid limestone of Derbyshire into successive stages or bands, which thin out northwards in proportion as the sedimentary strata of sandstone and shale augment. Now, when we proceed further north, into Scotland itself, we find these changes still further carried out. The limestone beds, of which (according to Professor Phillips) there are ten in number in Northumberland* parted by as many beds of shale, &c., attaining a thickness of about 1120 feet, are found to have dwindled down to about one-tenth of these dimensions, and their place to be occupied by a great series of sandstones and conglomerates, shales, and clays, with ironstones and coal-seams; the whole forming what is known as the "lower coal-series" of Scotland.

The lower coal-series of the Clyde basin represents in effect the Carboniferous limestone of England and Ireland, under altered conditions; and at its base there occurs a thick series of red sandstones and conglomerates, which are very fully developed in Ayrshire and along the southern shores of the estuary of the Clyde; these are known as "The Calciferous Sandstones."

The general section is as follows; and we shall still, for the purpose of comparison, retain the lettering of the stages as above :—

General Section of the Carboniferous Rocks of the Clyde Basin.

- Stage E. Upper coal-series, 840 feet.
- " D. { Sandstones and shales, feebly represented, about 500
- " C. } or 600 feet.†
- " B. Lower coal-series, consisting of six thin courses of marine limestone, from 50 to 100 feet in aggregate thickness, with interstratified grits, shales, coal, and ironstone; about 2200 feet.
- " A. Calciferous Sandstones; reddish calcareous sandstones, with contemporaneous trap rocks, &c., of great thickness (representing the Lower limestone shales of England).‡

The general and prominent feature in the Scotch series is the attenuation of the calcareous beds of the Carboniferous limestone stage,

* "Manual of Geology," p. 163.

† The Roslyn sandstone is considered by geological surveyors to be the representation of the millstone grit; but in the neighbourhood of Glasgow it cannot be identified.

‡ Explanation, p. 12, to Murchison's and Geikie's new Geol. Map of Scotland, 1862.

and their replacement by sedimentary strata with certain minerals, such as coal and ironstone, which are elsewhere found in the true coal-measures of stage E. The cause of this I have elsewhere shown to have been the existence, during the Lower Carboniferous period, of marine currents carrying sandy and muddy sediment from the northward. Now, as the existence of such sediment in the waters of the ocean is at the present day destructive of coralline life, so during this stage it was destructive of corallines, crinoids, and other marine animals, which were the great limestone builders of the Carboniferous period.

Special Features.—Amongst the special features of the Lower Carboniferous rocks of the west of Scotland, we may mention:—(1.) Earthy compact limestones, producing hydraulic cement. (2.) Black-band ironstones. (3.) Clay-band ironstones. (4.) Coal. (5.) Great development of red sandstones. (6.) Contemporaneous trap rocks (melaphyre, porphyrite, &c.), with beds of ash. As this last feature is not represented at Ballycastle (the trap-rocks of that district being eruptive), it may be omitted from our consideration in this place. The other features of resemblance I shall now briefly notice.

(1.) *Earthy Limestones.*—The limestones which occur at intervals throughout the Scotch Lower Carboniferous series, are generally in the form of thin compact earthy beds, differing much in appearance from the massive crystalline encrinital and coralline limestones of the north of England. The uppermost is the Garnkirk limestone, and the lowest underlies “the Hurlet Coal.” Their combined thickness, in the Glasgow district does not exceed 100 feet. They contain Carboniferous limestone species of the genera *Spirifer*, *Productus*, *Rhynchonella*, *Euomphalus*, &c., with crinoids and corals.

(2.) *Black-band Ironstones.*—The occurrence of black-band ironstones, interstratified with coal and black shales, is another feature. Though not exclusively found in the lower series, the principal beds are all found in a position below the upper marine limestone of Garnkirk, and therefore in the Carboniferous limestone series. The ironstones sometimes pass into coal, or cannah.

(3.) *Clay-band Ironstones.*—These occur in the same strata as the black-band seams, and I only mention them here as it will be seen they are also present at Ballycastle.

(4.) *Coal.*—Although the principal seams of coal are found in the upper series, a considerable number of thinner seams are found throughout the lower series, lying below the Garnkirk marine limestone. There is also “the Hurlet Coal” five or six feet in thickness, lying far down in the limestone series.

(5.) *Red Sandstones.* (“*Calcareous Sandstones*”.)—The great development of red and yellow sandstones at the base of the Lower Carboniferous series, is a remarkable feature, and one which we shall find paralleled when we come to consider the Ballycastle district. These red sandstones, sometimes calcareous—and containing plant remains—lie below the marine limestones, and may safely be considered to represent the Lower Lime-stone shale and yellow sandstone of the north of Ireland.

Having thus passed in rapid review the general, and some of the special, features of the Lower Carboniferous series of Scotland (the true representative of the Mountain Limestone and the subordinate lower shales), I think we shall find that these features are also characteristic of the Ballycastle coal-series, and that we shall be justified in considering the rocks of both districts, as the actual representatives in time of one another, and both as representing the Lower Carboniferous series of Britain.

Ballycastle Carboniferous Series.—These beds have been described by several authors,* and I only propose to refer to them here for the purpose of comparison with the Scotch series.

In general terms they may be described as follows:

- (3.) *Upper Beds.*—Reddish and grey sandstone, sometimes coarse-grained and conglomeratic; and shales with several seams of coal, black-band, and clay-band ironstone.
- (2.) *Middle Beds.*—Thin bands of fossiliferous limestone and shales.
- (1.) *Lower Beds.*—Red and yellow sandstones and shale, with one seam of black-band ironstone, and beds of conglomerate at the base.

The entire thickness of the series is unknown, but it probably exceeds 1,200 feet. The strata over some portions of the coal-field are capped by massive columnar beds of basalt and dolerite.

I now proceed to give details of two or three sections, measured along the cliffs. Of these, Sir R. Griffith has already furnished in his "Report" several accurate sections, with illustrations.

General Coal-series in Ballycastle Bay (furnished by Mr. Archibald Gray, Mine Manager).

		Fms.	Yds.	Ft.
First coal (<i>Splint seam</i>)	· · · ·	0	0	3
· Strata (sandstones and shales)	· · · ·	5	0	0
Second coal (<i>Hawksnest seam</i>)	· · · ·	0	0	3
Strata	· · · ·	40	0	0
Third coal (<i>Main seam</i>)	· · · ·	0	0	4
Strata	· · · ·	10	0	0
Limestone	· · · ·	0	2	2
Strata	· · · ·	40	0	0
Lower black band ironstone (about)	· ·	0	1	0

* By Dr. Berger and the Rev. W. Conybeare, in their paper on "The Geological Features of the North-East of Ireland," Trans. Geol. Soc. 1816. Mr. (now Sir R.) Griffith's "Survey of the Antrim Coal District," Report, 1829.

Section at Gob Colliery. (Fig. 1.)

This remarkable coast section, which is typical of the series, is given by Sir R. Griffith, and was also sketched by myself bed by bed. On comparing my own section with that of Sir R. Griffith, I find the upper portion corresponds exactly with his, but in the lower there is considerable divergence. The exact spots where the two sections have been taken may be different, which will in some measure account for the discrepancy. The total elevation of the cliff is 373 feet above the sea.

Cliff Section at Gob Colliery (showing relative Position of the Main and Coal Limestone.)

	Feet. Inches.
1. Columnar basalt,	51 0
2. Shale with black-band ironstone,	18 0
3. Reddish sandstone,	42 0
4. Black shale, with coal,	15 0
5. Massive reddish and white sandstone,	81 0
6. <i>Main coal</i> ,	4 0
7. Black shale and fire clay,	2 0
8. Impure coal,	2 0
9. Black shale,	16 0
10. Reddish sandstone,	30 0
11. Black shale and coal,	4 0
12. Reddish sandstone—sometimes a conglomerate,	36 0
13. Grey calcareous shales, with bands of flagstone,	26 0
14. Compact earthy limestone, with shale parting,	9 0
15. Strong calc. shale, sandy in lower part,	20 0
16. Massive coarse sandstone (white),	30 0

Sections at Mr. M'Gildowny's Mine (showing Details of Coal and Ironstone.)

	Feet. Inches.
1. Coarse reddish grit, becoming fine-grained and white at bottom,	" " 6
2. Black shale roof,	1
3. <i>Main coal</i> (variable)	3 feet to 4 6
4. Black-band ironstone,	1 0
5. Dark shale,	5 0
6. Clay-band ironstone—very rich (variable),	0 7
7. Black shale,	0 8
8. Black-band ironstone (variable),	1 0
9. Black shale,	8 0
10. Yellow sandstone, (more than)	15 0

The above sections will suffice to give an idea of the upper and central portions of the Carboniferous series. These beds are underlaid by a thick series of reddish sandstone, described by Sir R. Griffith as

underlying the magnificent mural cliffs of columnar dolerite of Fair Head. The base of the whole series is formed of yellow and white sandstone, and quartzose conglomerate, which, in Murloch Bay, may be seen resting directly on foliated mica-schist, and dipping towards the north-west, under the rocks of Fair Head. This section is shown along the shore at Boat Port, and is represented in the sketch (Fig. 2), taken at Boat Port, Murloch Bay, showing the basement conglomerate of the Carboniferous Series.

Limestone of Colliery Bay.—As bearing upon the age of the Carboniferous series in this district, by far the most important member is the band of limestone referred to above (p. 5), as lying ten fathoms below the *main seam of coal*, and also in the section at Gob Colliery. This bed varies from eight to nine feet in thickness, and is generally divided into two portions by a band of shale. It may be observed cropping out along the coast cliff at Star Colliery, as far as North Star Dyke, before reaching which it dips under low water, to the eastward, but reappears at Gob Colliery; and, opposite Carrickmore, rises into the cliff, and is lost to view beneath the basalt. This band of limestone is compact, earthy, probably dolomitic, and is generally well stored with shells and crinoidal remains. On seeing it, I was at once struck by its similarity to the Carboniferous limestone bands of the west of Scotland, near Glasgow and Paisley; some of which (as the "Arden limestone") possess hydraulic properties, and are worked for hydraulic cement.* It lies between two beds of shale, also charged with remains of mollusca, &c.; these beds form grassy slopes above and below the little scarp of the limestone in Colliery Bay.

This band of limestone may be regarded as occupying the position of the lower division of the Carboniferous limestone series, as it seems to be the first we meet with in the ascending order. If this be so, then the overlying strata with coal are the equivalents of the upper beds of the same formation under the Scotch Lower Carboniferous type. In this view I am supported by Mr. W. H. Baily, F. G. S., who, in company with Mr. A. M'Henry, has visited the district in order to investigate its palaeontological characters. Mr. Baily finds that the fossils, with which this band is richly charged, are Carboniferous Limestone forms, for the most part *representing the lowest beds of that formation*. A list of these fossils is subjoined (p. 13).

This view is further corroborated by a comparison of the fossil forms found in the limestone with those from the Carboniferous limestone series of the west of Scotland. In the "Transactions of the Geological Society of Glasgow," very complete lists are given of fossils from this series in the district of Paisley. We find that out of thirty-three species

* Mr. J. M'Gildowny, of Clare Park, informs me that the limestone of Ballycastle Bay is hydraulic, in this respect resembling that of the west of Scotland.

from Ballycastle, about fifteen, or fifty per cent. are common to the Carboniferous limestone beds of these districts.*

It is at present uncertain whether there are other beds of limestone interstratified with the coal-bearing rocks which overlie the limestone band of Colliery Bay. Mr. Gray informs me that none have been found by him; but Sir R. Griffith gives the details of a boring, made in 1816, at Barnish,† in strata supposed to overlie the main coal, in which a bed of limestone was reached at a depth of seventy-one yards. As the strata in the boring do not at all correspond with those overlying the limestone of Colliery Bay, we may assume, with Sir R. Griffith himself, that the bed here proved is not the same as that in Colliery Bay, but one probably occupying a higher position in the series.

The limestone of Colliery Bay is probably the lowest, or nearly the lowest, calcareous band (corresponding to the position of the Hurlet limestone of Paisley); and if we take the lower coal-series of Scotland‡ as a guide to the identification of the Ballycastle coal-series, we arrive at the conclusion, that the beds overlying the limestone of Colliery Bay belong to the Carboniferous limestone series, as well as those in immediate contact with the limestone itself.

Black-Band Ironstones.—The occurrence of these peculiar carbonaceous ironstones at Ballycastle is another feature of relationship to the lower coal-series of Scotland. Four of these are known; the uppermost 150 feet above the main coal (see section of Gob Colliery above, p. 6), then two in close proximity to this seam, and one 240 feet below the limestone of Colliery Bay. In Scotland, nearly all the black band ironstones occur in the Carboniferous limestone series.

Palaeontological Evidence.—This is at present far from complete, but so far as it goes, fully bears out the view of the identification of the whole Ballycastle coal-series with the Lower Carboniferous rocks of Scotland. The species which occur in the limestone of Colliery Bay, and the shales both above and below it, identify it with the Lower Carboniferous series. Some of these species are recorded by Mr. W. H. Baily from specimens collected by himself and Mr. A. M'Henry, the collector of the Survey. But not only have we Lower Carboniferous species in the limestone, but also in beds associated with the coal-seams themselves. At the Salt Pans Colliery, the shales lying between the "Splint" and "Hawksnest" coals contain in abundance *Lingula squamiformis*, a fossil which, as far as we have been able to ascertain, occurs only in the Carboniferous limestone series. In this position it is found in the lower coal-series of the west of Scotland, also low down in the

* Mr. M'Phail on the Geology of the Nitshill District, and Mr. Craig on the Geology of the Dalry District, "Transactions of the Geological Society of Glasgow," vol. iii. pt. 2.

† "Report," &c. *sup. cit.* p. 69.

‡ Upwards of 2000 feet thick, consisting of grits, shales, coal, ironstone, and their bands of limestone. See p. 3, *supra*.

Carboniferous limestone of the north of England, and in a similar position at Enniskillen. Taken by itself this may not be considered as determining the geological position of the beds, but it is at least a valuable corroboration of the views here advanced when taken in conjunction with the other features of evidence.

Conclusions.—It may be fairly stated that there is a strong general relationship, approaching identification, between the coal-series of Ballycastle and the Lower Carboniferous rocks of W. Scotland, representing the Carboniferous limestone of England and Ireland. We find a similar series of reddish grits and conglomerates at the base, overlaid by similar earthy limestones, black-band and clay-band ironstones, beds of coal, and coarse-grained grits and shales; while the palaeontological relations are, as far as known, analogous. Recurring then to the plan adopted above of dividing the Carboniferous rocks into representative stages, I suggest the following for those of Ballycastle.

Geological Stages of the Ballycastle Rocks (see above, p. 262).

- Stage E. Coal-measures (not represented).
- " D. Millstone grit (probably not represented).
- " C. Yoredale beds (uncertain).
- " B. Carboniferous limestone; coal-series of Ballycastle Bay and Murloch Bay, down to the shales underlying the limestone of Colliery Bay.
- " A. Limestone shale, yellow sandstone, &c.; red sandstones and conglomerates below the limestone, Colliery Bay, Carrickmore Bay, and Murloch Bay.

Changes in the Carboniferous Limestone Series of Ireland in its Extension Northwards.—The views advocated are in accordance with observation as applied to Ireland itself. The Carboniferous limestone of England undergoes, as we have already seen, a complete revolution in its mineral character when traced from the centre of that country into Scotland. Such changes involve certain physical conditions of the period of more than local influence, and it would have been strange if the Lower Carboniferous rocks of Ireland had escaped similar alterations of mineral character. In all probability the variations in both countries were very nearly identical. In each case during the formation of the limestone in the centre of England and of Ireland, in clear and limpid waters teeming with organised beings (limestone builders), these waters in a northerly direction became charged with muddy and sandy sediment; and were also in more immediate proximity to the land from whence this sediment was derived. This proximity gave rise to terrestrial conditions productive of beds of coal, and ironstone.

On a former occasion I have shown, that in formations composed partly of calcareous and partly of sedimentary members, the mutual relations of these are of an opposite character, and that the direction in which the one set of strata augments, the other will be found to undergo

attenuation.* Into the reasons for this law I need not here enter, but the Lower Carboniferous rocks of Ireland are an illustration of its truth. In the central portions of the country, this limestone assumes its greatest proportions, and the amount of sedimentary matter associated with it is comparatively unimportant. On the other hand, both to the southward and to the northward, the sedimentary materials sensibly augment to the disadvantage of the calcareous.

Confining our attention to the changes in a northerly direction, the observations of Griffith and Portlock fully bear out the statement I have made. This latter authority shows that in the county of Derry, the limestone is represented by a few nodular calcareous beds, irregularly interposed amongst sandstones and shales of considerable thickness,† and contrasts the greater development of limestone in a south-westerly direction as compared with that towards the north-east, where sandstones and shales predominate.‡ A change in the direction of the Lower Carboniferous type of Scotland takes place in the Carboniferous limestone of Fermanagh when traced into Londonderry; and, as I maintain, is still further carried out in the case of the Ballycastle coal-series, which lies in a position intermediate between Fermanagh and Derry on the one hand and the district of the Clyde basin on the other.

This gradual change of mineral character will be apparent from the following comparative section along the line here indicated.

Changes in the Lower Carboniferous Series along a North-easterly Line from Ireland to Scotland.

	Fermanagh.	Londonderry.	Ballycastle.	Clyde Basin.
Stage D.	Millstone grit, 250 ft.?	(uncertain).	(absent).	(Sandstones, &c.).
„ C.	Yoredale Beds, 650 ft.?	(uncertain).	(uncertain).	(uncertain).
„ B.	{ (A) Upper Limestone, } 250 „? Dark shales, and earthy Limestones ("calp,") 1000 „? Blue Limestone, } 500 „?	Thick series of sandstones and shales with thin bands of limestone.	Sandstones and shales with coal, b. b. iron-stone and earth limestone.	Sandstones and shales with coal and b. b. iron-stone, and thin bands of earthy limestones.
„ A.	Shales, Sandstones, and Conglomerates, } 200 „?	Yellow and red sandstones and conglomerates.	Red sandstones and conglomerates.	Calciferous sandstone series.

* "Quarterly Journal of the Geological Society of London," vol. xviii. p. 127.

† "Geological Report, Londonderry," &c., p. 561.

‡ I am glad to observe that Portlock refers to the resemblance of the Lower Carboniferous series of East Derry to the Scottish series. "Report," pp. 564-5. See also Griffith's Geological Map of Ireland.

From this table it will be seen that the changes in the Lower Carboniferous series are gradual along the line here indicated. A similar comparison might be instituted with similar results along a line drawn from the centre of Ireland through Ballycastle. In all cases it would be found that the sedimentary materials gradually replace the calcareous as we proceed northwards.

Physical Geography of the Period.—These observations lead to the inference that, throughout the Lower Carboniferous period, a large tract of land (or a continent) occupied the region of the North Atlantic Ocean. This primeval Atlantis was the source of the sedimentary materials of the period, which were distributed in diminishing quantities southward.

During this period, the ocean over the tracts now forming the central portions of England and Ireland was, for the most part, limpid and free from sediment (except during the stage of the calp in Ireland), and in this limpid sea, thus favourable to the development of marine life, those living forms, which were the limestone builders of the period, flourished, and the limestone of the Lower Carboniferous period was developed in its full vertical dimensions. From this central position it thinned away northwards, where it was replaced by sedimentary strata.

Towards the north-east and north, terrestrial conditions sometimes prevailed, favourable to the growth of plants and the formation of coal or ironstone.

During the same period similar terrestrial conditions prevailed towards the south-west of the British islands, giving origin to the sedimentary strata of the Lower Carboniferous period in Devonshire and the southern districts of Ireland.

Appendix to Mr. Hull's Paper.

ON THE FOSSILS OF THE BALLYCASTLE COAL-FIELD, COUNTY ANTRIM. By WM. HELLIER BAILY, F. G. S., &c.

At Mr. Hull's request I append a note to his paper on the fossils formerly collected from this coal-field, and others recently obtained by myself and Mr. Alexander M'Henry, of the Geological Survey.

The following are the species of plants determined:—

[The mark \times prefixed to species is intended to indicate its comparative abundance.]

Sigillaria reniformis (Brong.) in shale.

Stigmaria ficoides (Brong.), with attached rootlets, in shale.

\times \times " " in sandstone.

" " var. *undulata*, in sandstone.

Aspidaria quadrangularis (Presl.) Morris C. Brit. Foss. 1854, p. 2.

" syn. *Lepidodendron tetragonum* (Sternberg) in shale.

Lepidostrobus variabilis (Lindley) in shale.

Sagenaria dichotoma (Sternberg).

syn. *Lepidodendron Sternbergii* (Brong.) in shale and sandstone.

„ „ (Sternb. sp.), according to Geinitz.

syn. *Lepidodendron aculeatum* (Sternb.) in sandstone. „ *Veltheimiana* (Goeppert).

syn. *Knorria imbricata* (Sternb. sp.) two varieties in sandstone.

× × „ *rimosa* (Presl.) in sandstone.

Although but few species are enumerated in this list of fossil plant they are such as appear to indicate an alliance with a Lower Carboniferous flora. *Sigillaria*, with its roots or rhizome *Stigmaria*, is of frequent occurrence; this group, including *Lepidodendron*, to which it is closely allied, and its fruit *Lepidostrobus*, belongs to the Lycopodiaceae, and is the most important and universally distributed of all the Coal Measure plants. To the genus *Sagenaria* of Brongniart, *Lepidodendron* of Sternberg, also belonging to the family Lycopodiaceae, Professor Goeppert refers *Knorria imbricata*, which he considers to be identical with *Sagenaria Veltheimiana*, the most common species in the lower carboniferous rocks. This species is stated by Professor Geinitz* to occur in the Coal formation at several localities in Saxony, and by F. A. Roemer in the Posidonomya schist formation at Lauthenthal, and in the Newer grauwacke of Clausthal, &c. In Irish strata it has been identified by me in sandstone, from Carntel, Tyrone, probably equivalent to that of the Ballycastle section; in the carboniferous slate of Tallow Bridge, County Waterford, where it is remarkably abundant; also in the upper old red sandstone of Kiltorcan, County Kilkenny. This plant, under the name of *Knorria imbricata*, is also stated by Professor H. R. Goeppert† to occur in the Transition formation (Grauwacke) in Silesia; at Magdeburg in Saxony; in the province of Perm, Russia; and from the coal mines of Orenburg, on the borders of Asia; whilst Lindley and Hutton record its occurrence in the Ketley coal-field of Shropshire.‡ Some of the stems of *Sagenaria rimosa*, are nearly a foot in diameter, and are, in the pinkish sandstone, associated with numerous other plant fragments, particularly *Stigmaria*, possibly the Rhizomes or roots of this and allied species.

The absence of *Ferns* and jointed *Calamites*, which are usually so abundant in the true coal measures, and the presence of *Sagenaria* (or *Knorria imbricata*), uniformly striated and spirally imbricated plants, is a remarkable feature in this collection from the Ballycastle collieries, offering considerable support to the probability of their alliance with the flora of the Carboniferous limestone and culm.

* "Darstellung der Flora des Hainichen Ebersdorfer," &c., p. 57.

† "Les Genres des Plantes Fossiles," 1841.

‡ "Fossil Flora of Great Britain," vol. ii., p. 43.

The fossils occurring in the beds of limestone and associated shales are principally Molluscan shells, and are, for the most part, typical Carboniferous limestone fossils, some of them being exclusively characteristic of the lower limestone strata.

The following is a list of the species from the limestone and shale:—

ZOO PHYTA.

× × × *Chætetes tumidus*.

ECHINODERMATA.

× *Archæocidaris Urii*.

× × × *Poterioerinus crassus*.

 ,, *quinquangularis* (?)
Actinoerinus (species indeterminable).

CRUSTACEA.—*Trilobita*.

Phillipsia Derbiensis.

Griffithides longiceps.

MOLLUSCA.—*Polyzoa*.

Ceriopora gracilis.

Fenestella antiqua, syn. *F. plebeia* M'Coy.

Brachiopoda.

× *Productus giganteus*.

× ,, *longispinus*.

× ,, *semireticulatus*.

× × × × *Chonetes Hardrensis*.

× × *Spirifera lineata*.

× × ,, *bisulcata*.

× × × *Rhynchonella pleurodon*.

× × × *Lingula squamiformis* (in black shale above the limestone).

Conchifera.

Aviculopecten (species indeterminable)

× × × *Axinus deltoideus*.

 ,, (species indeterminable).

× × × *Leda attenuata*.

Cypriocardia cuneata ?

Edmondia, (species indeterminable).

Sanguinolites discors (?)

Myalina Verneuilii ?

Gasteropoda.

Macrocheilus ovalis.

Murchisonia angulata De Kon. (not Ph. Pal. Foss).

Pleurotomaria (species indeterminable).

Nucleobranchiata.× × *Bellerophon Urii.**Cephalopoda.**Orthoceras Steinhauerii.*, *dactyliophorum.*, *subcentrale (?)***PISCES.***Helodus planus (?)* palatal teeth.*Ctenacanthus*, defence spine, in black shales above limestone.*Amblypterus (?)* Portlock Geol. Rep., p. 462., black shales, do

Fish scales, bones and teeth, black shales, do.

On referring to the above list it will be seen that only one kind of Coral was observed—*Chætetes tumidus* (Stenopora of Morris's Catalogue of British Fossils), a small branching variety of a species belonging to the *Farositidae*. It is abundant on the surfaces of some of the shales, accompanied by numerous Crinoid fragments, and is a characteristic carboniferous limestone species, frequent in the lower shales of the series.

Spines of *Archæocidaris Urii*, an Echinoderm characteristic of the lower shales of the Carboniferous limestone in Ireland, are not unfrequent on the weathered surfaces of some of the limestone slabs. This species is included in the lists of Carboniferous limestone fossils given in Mr. Hugh M'Phail's paper on the Levern Valley, Renfrewshire,* and that of Dalry, Ayrshire, by Mr. Robert Craig.†

Crinoid stems and joints abound in the limestone and associated shales of the section exposed on the Ballycastle shore. The large stems referred to, *Poteriocriinus crassus*, I believe to be exclusively a limestone species, in Ireland it is of frequent occurrence in the lower shales, together with *Actinoerinus*, the species of which from these beds are indeterminable.

Crustacea of the order Trilobita are represented by two species which appear to be identical with *Phillipsia Derbyensis* and *Griffithides longiceps*, both exclusively confined to the Carboniferous limestone.

Polyzoan mollusca were found to be rare, two forms only having been recognized in the limestone, *Ceriopora gracilis* and *Fenestella antiqua* (*F. plebeia*, M'Coy), both of which are recorded as having a stratigraphical range from the Upper Devonian to the Carboniferous limestone series.

Of Brachiopoda eight species were collected from the limestone and associated shales; of these, *Productus giganteus*, *longispinus*, and *semireticulatus*, characteristic Carboniferous limestone species, are included in the lists of fossils from Scotch strata, before alluded to; an allied shell, *Chonetes Hardrensis*, was found to occur in the greatest profusion, cover-

* "Trans. Geol. Soc. of Glasgow," vol. iii., pt. 2, p. 534, *et seq.*† *Ibid.*, p. 271, *et seq.*

ing the surfaces of slabs and detached in the shales, showing its finely striated exterior, and the interiors of both valves in beautiful preservation. This small species is found, as recorded by Mr. Thomas Davidson,* in the limestones and shales of many English, Scottish, and Irish localities. Its stratigraphical range is stated to be from the Devonian to the Coal measure series. In Ireland, I have identified it from coal measures in the County Clare, at various localities in carboniferous limestone, and the lower shales; in the Scotch lists before mentioned it is stated to occur in upper, middle, and lower limestone.

Spirifera bisuleata, a species common in the Coalbrookdale collieries, and *S. lineata*, exclusively a Carboniferous limestone species, are not uncommon in the limestone on the Ballycastle shore. In the Scotch lists these species are included as occurring in upper, middle, and lower limestone.

Rhynchonella pleurodon is abundant in the shales of the Ballycastle limestone; it may be considered a characteristic limestone fossil. The stratigraphical range of this species, as given in Morris's Catalogue, is from the Upper Devonian to Carboniferous limestone; according to the Scotch lists it occurs in upper limestone.

Lingula squamiformis is a frequent fossil in the black shales above the limestone near the Salt Pans Colliery, being associated with branching plants and fish remains; it is exclusively a Carboniferous limestone fossil, occurring in Ireland, most frequently in the lower shales. In the Scotch lists it is recorded as occurring in the upper limestone.

Of the Lamellibranchiata, or ordinary bivalve shells, about eight species were collected from the limestone and shales, the most abundant being *Axinus deltoides* and *Leda attenuata*; the former species having a range from Upper Devonian to Carboniferous limestone, the latter occurring in Carboniferous limestone and shales at various localities in England and Scotland and Ireland. This species is included in the Scotch lists from the middle and lower limestone. Of the remaining bivalve shells, those determinable are exclusively Carboniferous limestone species.

Only three distinct forms of univalve shells were observed, all being species exclusively from Carboniferous limestone.

A Nucleobranch shell, *Bellerophon Urii*, was found to be not uncommon in the limestone and associated shales. In the catalogue of British fossils its range is given as Upper Devonian to carboniferous limestone; it has been identified by me from Coal-measure shales in the County Limerick, and lower limestone shales in the County Cork. It is included in the Scotch lists as occurring in the middle and lower limestone.

The few Cephalopod shells, collected from the limestone and shale of Ballycastle, are small but characteristic; two species only have been satisfactorily identified, viz., *Orthoceras dactyliophorum* and *O. Steinhauerii*; the former has also been identified from the limestone at St. Doulagh's,

* "British Carboniferous Brachiopoda," Pal. Soc., p. 187.

County Dublin, and the Coal-measures of Foynes Island, County Limerick, and the latter from the Lower Carboniferous limestone of the County of Cork and the Coal-measures shales of Loughshinny, County Dublin, and corresponding shales in the County Meath.

From the black shales above the old Salt Pans Colliery, in which the *Lingula squamiformis* were so plentiful, we obtained a small fish spine, probably of the genus *Ctenacanthus*, accompanied by scales and other fish fragments. In the small collection formerly made from Ballycastle (Portlock series), now exhibited at the Royal College of Science, Stephen's Green, Dublin, with the collection of the Geological Survey of Ireland, is a considerable portion of a small fish which has been, doubtfully, referred to *Amblypterus*, by General Portlock,* and appears to have been obtained from the same dark shales. From the limestone shale on the shore we collected two small palatal fish teeth in juxtaposition, which appear to resemble *Helodus planus*.

The absence of the usual Coal-measure assemblage of fossils, such as the Ferns and *Calamites*, amongst the plants already alluded to, and amongst Molluscan shells, that of *Aviculopecten papyraceus*, *Posidonomya membranacea*, and *Goniatites crenistria*, which are usually present in such profusion in the Upper Carboniferous or true Coal-measure strata, together with the occurrence of so many species of characteristic Carboniferous limestone fossils, some of them being even peculiar to the lower limestone series, appears to me to assist materially in confirming the author of the preceding paper in his views as to the correlation of these strata with those of the west of Scotland, and consequently, increases the probability of their belonging to the lower division, or Carboniferous limestone series.

* Geological Report on Londonderry, &c., p. 462.

